AD-A231 765

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. Agency Use Only *(Leave blank).*

2. Report Date. Feb 7-9, 1990

3. Report Type and Dates Covered.

4. Title and Subtitle.
Influence of Bathymetry on the Propagation of Signals and Noise

5. Funding Numbers.
Program Element No.
Project No.
Task No.
Accession No. DN259009

6. Author(s).
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7. Performing Organization Name(s) and Address(es).
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529-5004

8. Performing Organization Report Number.
AB 90:245:037

9. Sponsoring/Monitoring Agency Name(s) and Address(es).
Office of Naval Research (AEAS)
Stennis Space Center, MS 39529-5004

10. Sponsoring/Monitoring Agency Report Number.
AB 90:245:037

11. Supplementary Notes.
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12a. Distribution/Availability Statement.

Approved for public release; distribution is unlimited.

12b. Distribution Code.
D

13. Abstract *(Maximum 200 words).*

The ambient noise field is a complex and highly variable phenomena with many components, including contributions due to shipping. Spatial characteristics (eg., the horizontal directionality) of the ambient noise field have been measured with towed line arrays in many of the major water masses of the world. This paper will address the effects of bathymetry on the propagation and measurement of ambient noise. It is shown that, in many cases, the horizontal directionality of the ambient noise can be fully understood only when the bathymetry along the propagation paths has been considered. Examples of measured data will be presented illustrating the effects of bathymetric stripping and bathymetric shielding on the spatial character of the ambient noise. Other examples of measured data will be shown demonstrating that bathymetric influences are not limited to a narrow frequency range. In addition, modelled data will be used to illustrate the effects of the surrounding bathymetry on noise and signal propagation.

14. Subject Terms.
(U) Reverberation; (U) Antisubmarine Warfare; (U) Active Sonar

15. Number of Pages. 5

16. Price Code.

17. Security Classification of Report.	18. Security Classification of This Page.	19. Security Classification of Abstract.	20. Limitation of Abstract.
U	U	U	SAR

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Influence of Bathymetry on the Propagation of Signals and Noise

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ABSTRACT

The ambient noise field is a complex and highly variable phenomena with many components, including contributions due to shipping. Spatial characteristics (eg., the horizontal directionality) of the ambient noise field have been measured with towed line arrays in many of the major water masses of the world. This paper will address the effects of bathymetry on the propagation and measurement of ambient noise. It is shown that, in many cases, the horizontal directionality of the ambient noise can be fully understood only when the bathymetry along the propagation paths has been considered. Examples of measured data will be presented illustrating the effects of bathymetric stripping and bathymetric shielding on the spatial character of the ambient noise. Other examples of measured data will be shown demonstrating that bathymetric influences are not limited to a narrow frequency range. In addition, modelled data will be used to illustrate the effects of the surrounding bathymetry on noise and signal propagation.

INTRODUCTION

The ambient noise field is a complex and highly variable phenomena with many components, including contributions from acoustic energy radiated by surface shipping that may be modified by the effects of transmission along complex oceanic paths from the noise sources to the receiver. In many major water masses of the world, spatial characteristics (eg., the horizontal directionality) of the ambient noise field have been measured with towed line arrays similar to the seismic streamers employed in geophysical petroleum

exploration. Specialized techniques have been developed to process and analyze the raw data produced by these towed arrays to achieve an understanding of the mechanics responsible for the underlying directional noise field. This paper will use two of these data processing and analysis products derived from measured data, namely the noise rose and the noise bouquet, to address the effects of bathymetry on acoustic propagation and the directionality of the low frequency noise field. Other examples of measured data will be shown to demonstrate that bathymetric effects are not limited to a narrow frequency range. Finally, a new processing product, the reverberation density rose, will be presented through the use of modeled data to illustrate the effects of surrounding bathymetry on the reverberation field produced by a monostatic active sonar.

BACKGROUND

The horizontal directionality of the ambient noise field is estimated by the Wagstaff Iterative Technique (WIT) algorithm[1]. WIT is a constrained iterative restoration algorithm that restores some of the high-order spatial harmonics filtered out by the low-pass spatial response of the array. The present version contains corrections for array tilt, three-dimensional beam-response patterns, and noise-field vertical arrival structure[2].

Figure 1 is a block diagram of the WIT estimation algorithm. WIT begins by making an initial estimate of the horizontal directionality of the ambient noise field for a single frequency, N_0 (polar plot to the left in Figure 1), and convolves this estimate with the beam pattern of a horizontal array on several headings. This results in estimates of the beam noise levels, $\hat{b}_i$, which are compared to the measured beam noise levels, b_i (uppermost polar plot in Figure 1) along the same headings. The differences obtained during this comparison, $\Delta\hat{b}_i$, are used to modify the estimate of the noise field. The modified estimate of the noise field, $\hat{N}_i$ (lowest polar plot in Figure 1), is the new input and the process is repeated until the sum of the differences between the estimated beam

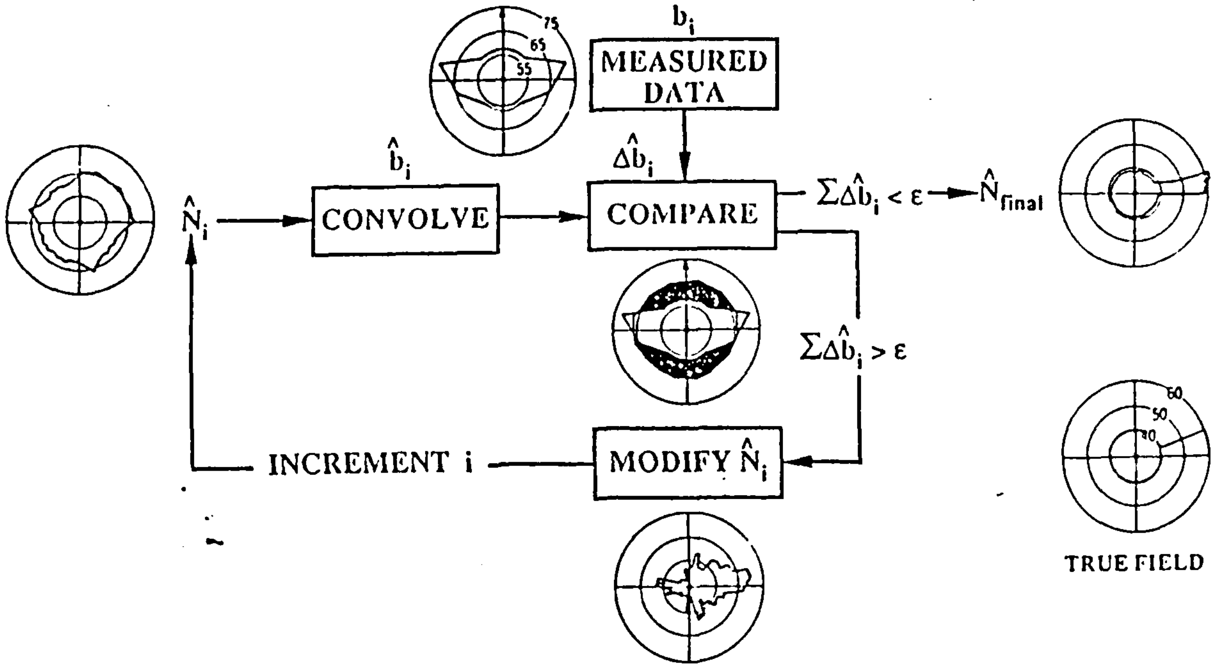

Figure 1. Block diagram of the WIT algorithm.

noise levels and the measured beam noise levels is below a set threshold, ε. The noise field estimate which achieves acceptable differences is considered to be the final estimate of the horizontal directionality of the ambient noise field, $\hat{N}_{final}$. The final product is plotted in polar fashion and is called a noise rose. For the example noise roses in Figure 1, the true field (simulated data in this example) is the noise rose in the lower right to which the $\hat{N}_{final}$ noise rose (achieved after only twelve iterations) in the upper right can be compared.

The noise rose is for a single analysis frequency. The equivalent information for many frequencies can be displayed in a color polar plot (not shown) called a noise bouquet. The use of these two products can readily indicate the directions of low and high noise areas at a given measurement site.

RESULTS

The effects of bathymetric shielding are relatively obvious and easily envisioned. The effects of bathymetric stripping, on the other hand, are similar but not as easily recognized. Figure 2 shows the results of PE (Parabolic Equation) model propagation loss predictions for 100 Hz along two different propagation paths to the same deep receiver location from

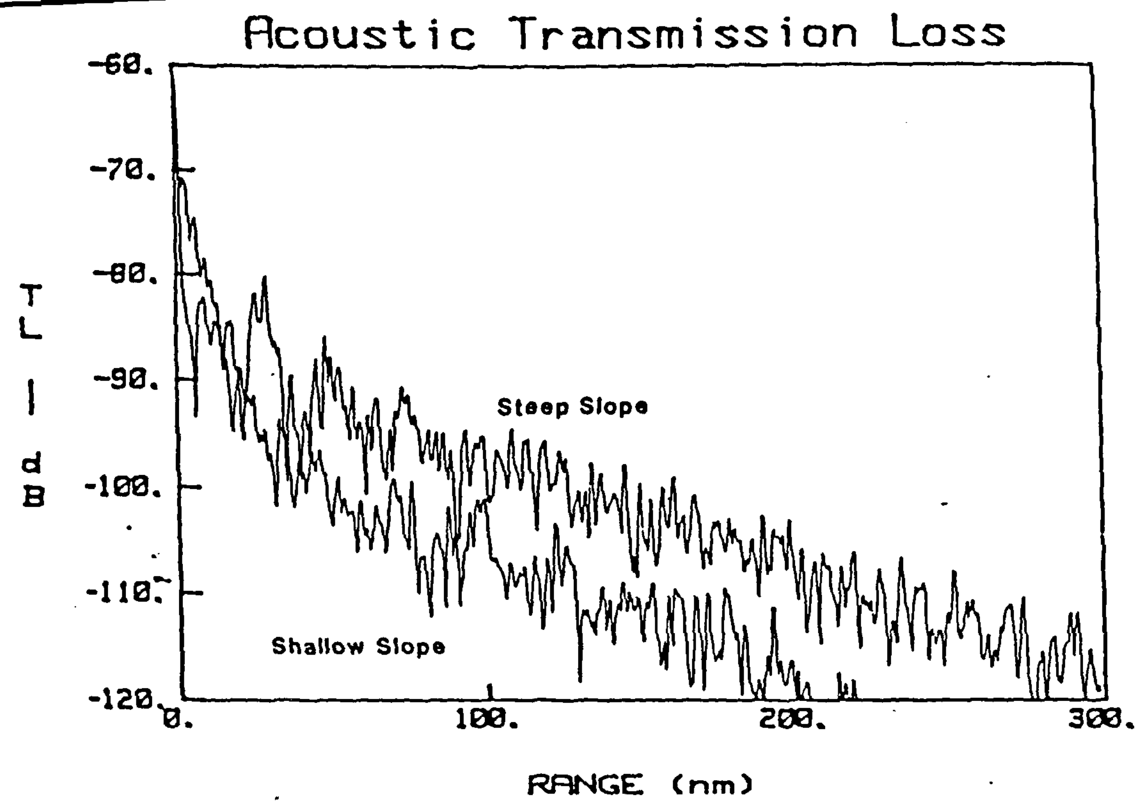

Figure 2. Overlay of the results of PE model predictions for propagation down a steep slope and down a shallow slope.

source locations on a relatively shallow area. One propagation path was over a shallow sloping bottom while the other was along a steep sloping bottom. From Figure 2, it can be seen that the predicted propagation loss for propagation down the steep slope relative to propagation down the shallow slope is approximately 7 to 10 dB better at 300nmi. This result is not unexpected since propagation down a shallow slope has more opportunity for bottom interaction, and thus undergoes more attenuation, than propagation down a steep slope.

The effects of this type of bathymetric stripping can be seen in Figure 3. Figure 3 is the measured horizontal directionality of the ambient noise (noise rose) corresponding to the PE model predictions in Figure 2, and shows essentially an ambient noise field dominated by discrete sources (i.e., ships). The ambient noise to the west of north is approximately 7 dB greater than the ambient noise to the east of north. The densities of shipping along both of these propagation paths are relatively the same. Therefore, the dramatic difference in the directional ambient noise seen in Figure 3 can be attributed to the propagation paths themselves. Indeed, the shipping noise to the west of north propagates

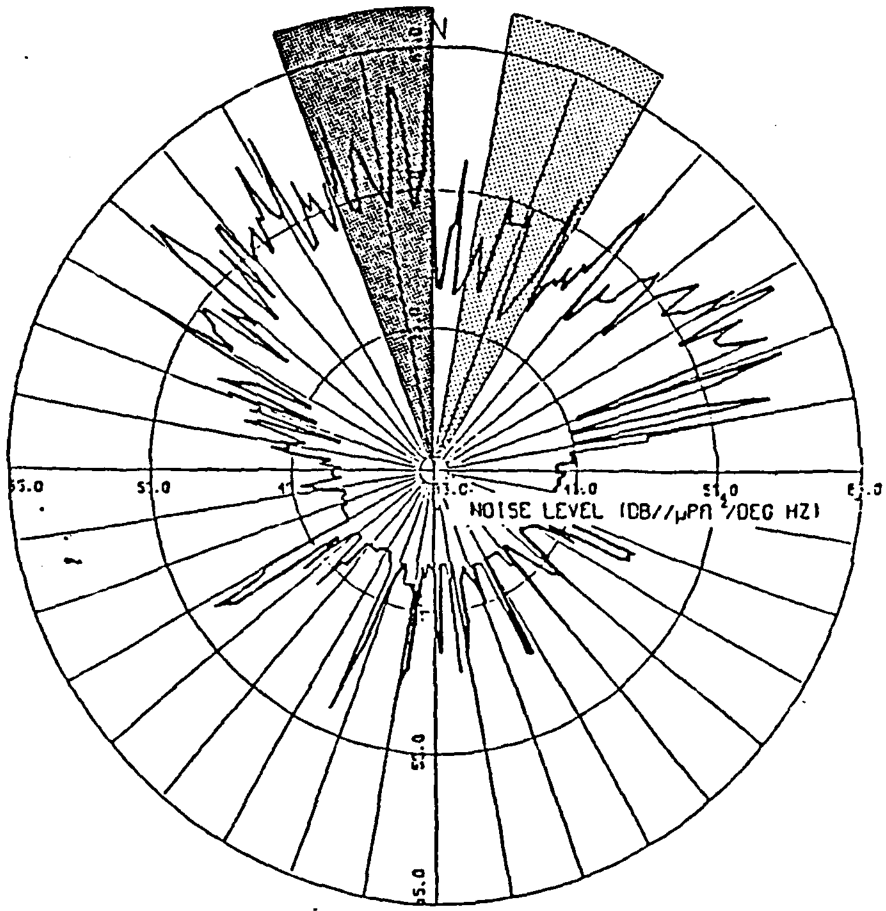

Figure 3. Horizontal directionality of the ambient noise illustrating the effects of bathymetric shielding.

down a steep slope (very little batymetric stripping), while the shipping noise to the east of north propagates down a shallow slope (high levels of batymetric stripping). The quantitative effects of the difference in propagation paths on the ambient noise agree well with the predicted differences shown in Figure 2.

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